WATER QUALITY OF LULU LAKE

kenora district,
township of pellatt

M. F. P. Michalski

1972

The Honourable
James A. C. Auld
minister

Everett Biggs
deputy minister

Ministry
of the
Environment

Ontario

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WATER QUALITY
OF
LULU LAKE
KENORA DISTRICT,
TOWNSHIP OF PELLATT

1972

by

M.F.P. Michalski
Biology Section
Water Quality Branch
Ministry of the Environment

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SUMMARY AND CONCLUSIONS

The enriched nature of Lulu Lake was evinced by low Secchi disc readings, relatively high surface water concentrations of phosphorus and nitrogen and by high standing stocks of phytoplankton dominated by the blue-green "water-bloom" forming species Anabaena flos aquae. The close proximity of Lulu Lake's chlorophyll-Secchi disc relationship to other relatively productive waters in southern Ontario substantiates the eutrophied status of the lake.

Since the current biological and chemical status of Lulu Lake is critical and as more evidence is appearing which demonstrates that phosphorus inputs from septic tank-tile field systems produce eutrophication problems, further development of the lake should not be considered unless it can be conclusively demonstrated that the sewage facilities provided will not undermine future water quality. Facilities provided should prevent organic wastes, bacteria and/or nutrients from gaining access to the lake.

Cottagers should be aware that unless artificial nutrients, including phosphorus and nitrogen, are kept from entering the lake, further degradation in water quality will materialize. In this regard, every effort should be made to ensure that nutrients from sink and laundry wastes, as well as seepage from septic tank systems and lawn and garden fertilizers do not enter the lake.

CURRENT PROGRAMMES RELATED TO COTTAGE POLLUTION CONTROL

The following summarizes the programmes currently underway relating to the Ministry's involvement in inland recreational lakes.

Cottage Pollution Control and Recreational Lakes Programme

Personnel of the Ministry are attempting to bring a number of stress factors on recreational lakes (i.e. increasing shoreline development, the disappearance of sports fish species in a lake, the growths and decay of excessive quantities of aquatic plants (i.e. weeds) and algae and the inadequate disposal of human wastes) under control using a number of programmes. The Cottage Pollution Control and Recreational Lakes Programme was initiated in 1967 and was expanded in 1970 to assess and solve the cottage waste disposal problem in recreational lakes. As part of this overall effort, three ongoing studies are currently underway.

1. An evaluation of existing waste disposal systems and enforcement of repairs to those found to be unsatisfactory is being carried out by staff of the Private Waste and Water Management Branch. In 1973, cottages on the shorelines of Rice, Balsam and MacLean lakes in the southern part of the province were surveyed; additionally, approximately 1,200 premises on Lake of the Woods near Kenora were inspected. Since 1970, more than 15,000 units on 39 lakes have been evaluated. Owners of premises found to be polluting or causing nuisances or where drinking water quality is unsatisfactory are notified and advised that corrective action would be required.

2. Water quality evaluations are carried out each year on a selected number of lakes where pollution problems are suspected (since 1970, seventy-six lakes have been surveyed). During the ice-free season of 1973, nine lakes in the northwestern part of the province including Loon, Warnica, Lottit, Trout, Surprise, Two Island, Island, Hazelwood, and Oliver lakes were surveyed. In addition, a totally undeveloped lake near Huntsville was studied in 1972 and in 1973 in order to obtain information relating to natural water quality conditions. These data will be extremely useful in clarifying relationships between natural and artificial pollutional inputs in Ontario's Precambrian recreational lakes area.
3. Research is currently being carried out to improve knowledge concerning relationships between septic tank-tile file systems and bacterial and nutrient translocations to lakes where shallow soils overlay impervious bedrock. Additionally, studies to assess modifications to conventional septic tank-tile field systems and alternative methods of private waste disposal are underway. For example, scientists and engineers of the Ministry are involved in a number of pilot scale studies which would determine the effectiveness of various septic tank and/or tile bed additives as phosphorus complexing agents.

"Self-help" Chlorophyll-Secchi Disc Programme

In 1971, staff of the Biology Section, Water Quality Branch, initiated a "Self-Help" recreational lakes water quality evaluation programme on seventeen lakes. The study involves the collection of information on water clarity as detected using a Secchi disc and abundance of algae as refelected by chlorophyll a concentrations. The fact that in excess of sixty lakes were sampled in 1972 and one hundred and twenty-five lakes in 1973 by individual cottages, cottagers' associations and/or shoreline residents reflects the successful nature of the study and the degree of public interest in problems relating to pollution in recreational lakes. It is expected that the information, if continued on a long-term basis will be extremely useful in assessing whether changes in water quality are materializing so that remedial measures can be implemented before conditions become critical.

Most certainly, the enthusiasm of participating individuals and the educational benefits which are derived from direct involvement makes the study one of major significance for the Ministry, both in terms of promoting good public relations and advancing an understanding of water quality problems in recreational lakes.

Lake Reclamation and Enhancement

(a) Effects of phosphorus removal on lake water quality.

Personnel of the Water Quality Branch have assessed the effects of phosphorus reductions on water quality in two Precambrian Shield lakes - Little Otter Lake near Parry Sound and Gravenhurst Bay near Gravenhurst. Following the elimination of phosphorus inputs to Little Otter Lake and significant loading reductions from the Gravenhurst Sewage Treatment Plants, dramatic water quality improvements materialized within a single year. For example, water transparencies increased, phytoplankton densities, chlorophyll a concentrations and total phosphorus levels diminished significantly. Needless to say, the results of both lake-scale studies are encouraging to future management programmes aimed at improving and restoring water quality in similarly affected lakes.

(b) Phosphorus inactivation using chemical precipitants

Under certain requirements of specialized water use, there exists a need for impounded water of low turbidity. For example, the farm pond used for watering livestock should be free from heavy growths of blue-green algae for the health of the livestock. Scientists and biologists are currently evaluating the effectiveness of various complexing aids as a means of inactivating phosphorus. However, before coagulant aids are condoned for widespread use, both short and long-term effects on benthic production, zooplankton populations and/or periphytic conditions as well as relationships to phytoplankton stocks must be carefully assessed.

(c) "Operation Weed Removal"

As part of an overall watershed management study in the Kawartha-Trent area, mechanical removal (harvesting) of aquatic vegetation is being assessed on a pilot scale basis in selected areas in the southern section of Chemung Lake as a potential method for improving or optimizing water use. Mechanical harvesting consists of cutting the plants and removing cuttings from the lake to avoid nuisances caused by large quantities of drifting and decomposing plant material. In contrast to chemical control, the technique does not introduce toxicants into the water, provides immediate relief from prolific weed growths and creates a significant "nutrient-drain" from the lake.

Individuals are invited to contact staff of the Biology Section, the Ministry of the Environment in Toronto, (telephone 248-3058) for further information regarding the aforementioned programmes.

INTRODUCTION

Over the past few years an increasing awareness and concern for problems of pollution in recreational lakes has materialized as a consequence of accelerated cottage development. Manay individual cottagers, cottagers' associations and permanent shoreline residents have requested that complete water quality evaluations be carried out to assess the degree of pollution in lakes. Exhaustive physical, chemical, bacteriological and biological evaluations collected on a regular basis through the ice-free season for a large number of lakes are beyond the financial and logistical capabilities of personnell involved in water management programmes, and in light of recent studies, are not necessary in order to categorize the quality of recreational waters. An explanation of water quality problems in recreational lakes is provided in Appendix A.

In 1971, a practical but effective programme which involved the collection of data on water clarity (obtained by means of a Secchi disc) and algal populations (measured as chlorophyll concentrations) was initiated on eighteen lakes throughout the province. At Lulu Lake only, additional biological and chemical information was collected on August 26, 1972. This report presents the data collected with a view to defining the current state of enrichment or trophic status of the lake and comments on the relationships between water quality and future development schemes.

DESCRIPTION OF THE STUDY AREA

Lulu Lake is located in the Township of Pellatt, District of Kenora, approximately 12 miles northwest of Kenora. The lake is fed primarily from the Rosina Lake - Bell Lake system via a small creek which opens into the west end of Lulu Lake. A single stream drains from the east end of the lake to Lake Louise and eventually to the Winnipeg River.

Various physical characteristics of the lake are tabulated below:

Maximum depth - 39 feet
Mean depth - 18 feet (approximately)
Area - 1,478 acres
Length of shoreline- 13.0 miles (including three islands)

Lulu Lake is situated in the western portion of the Precambrian Shield in impervious, weathered bedrock of metaphorphic origin. A shallow, coarse-textured sandy loom with numerous clay pockets covers the bedrock. The surficial terrain is characterized by numerous outcroppings of metamorphic rock. An estimated 200 cottages currently exist along the northern, western and southwestern shoreline. A single campsite having five house trailers exists on the lake shoreline; domestic wastes from each unit are transported to the Kenora sewage treatment plant.

METHODS

Chlorophyll-Secchi disc programme

Water clarity which governs the depth of light penetration, is one of the most important parameters used in defining the trophic condition of a lake and can be measured using a Secchi disc. The disc is divided into black and white alternating quadrants and is lowered into the water on a graduated line until the quadrants cannot be distinguished. The depth at which the disc just disappears is termed the Secchi disc depth. As depicted in Figure I, Secchi disc depths are substantially greater in lakes having low phytoplankton (microscopic free-floating algae) numbers than in lakes characterized by high algal densities and excessive vascular aquatic plant growths. Secchi disc readings were taken on eleven occasions during the summer and early fall of 1971 in a deep-water section of Lulu Lake. Usually, two readings per visit were obtained; a mean of the two readings was recorded as the Secchi disc depth.

Chlorophyll a is the amount of photosynthetic green pigment in algae and its concentrations can be used as a rough indication of the extent of biological activity in a lake at the time of sampling since it is regulated by all of the combined physical, chemical and biological factors which affect algal production. Chlorophyll samples were taken on each visit to the lake by lowering a 32-ounce bottle provided with a restricted opening to the approximate location of the 1% light level determined as twice the Secchi disc. This depth approximates the lower limit of algal production in a lake. The samples were immediately preserved with 10-15 drops of a 2% magnesium carbonate solution and shipped to the Ministry of the Environment's Laboratories in Toronto.

Field investigations - August 26, 1971

Personnel of the Biology Section, Ministry of the Environment (formerly the Ontario Water Resources Commission) carried out a study to clarify limnological characteristics of Lulu Lake on August 26, 1971. Biological and chemical samplings were completed at a single location approximating the deepest section of the lake.

Temperature, dissolved oxygen and pH measurements were determined in the field at surface, 10, 20 and 26 feet. Chemical samples representing the euphotic zone (determined as twice the Secchi disc depth) and a depth of 26 feet were taken. In order to identify and enumerate algae, a single euphotic zone composite sample was secured and immediately preserved with Lugol's Iodine solution. All samples were kept cool and forwarded to the Ministry of the Environment Regional Laboratory in Thunder Bay or to Toronto for analyses.

Laboratory methodology

Nutrient analyses were performed for total phosphorus (as mg/l P) and total Kjeldahl, free ammonia, nitrate and nitrite nitrogen (as mg/l N). Also, determinations for iron (as mg/l Fe) and alkalinity (as mg/l $CaCO_3$) were completed. The chlorophyll samples were filtered using a 1.2 u Millipore filter and analysed following the methods of Brydges (1971).

The single algal sample was concentrated by allowing the cells to settle for 72-96 hours, and then syphoning the overlying liquid. Subsequently, the cells were re-suspended and a 1-ml aliquot was pipetted into a Sedgwick-Rafter counting cell. All of the algal forms were identified to species where possible and to genus otherwise at a magnification of 200X. Numerical results were recorded as areal standard units (a.s.u.) per millilitre. One areal standard unit is equal to an area of 400 square microns (Whipple 1914). The areal value was employed because of its usefulness in measuring standing stocks of algae and because it is extremely useful when relating algal levels to water quality problems. Depending upon the density of the concentrate, strips or fields were counted. To render results statistically accurate, between 150 and 200 organisms per millilitre were identified and measured.

DISCUSSION OF RESULTS

Physical aspects

Temperature and light penetration

On August 26, 1971 water temperatures were uniform from surface to bottom (Figure 2a), indicating complete vertical mixing by wind and wave action.

Secchi disc measurements (Table I) ranged between 4.0 and 10.0 feet and averaged 6.3 feet. Recent evidence from in-depth studies carried out in Lakes Joseph, Rosseau and Muskoka in the Muskoka Lakes area of the province suggests that lakes having Secchi disc readings less than 9.8 feet are eutrophic or enriched in nature while those exceeding 16.4 feet are oligotrophic or unenriched in status. Lakes having Secchi disc

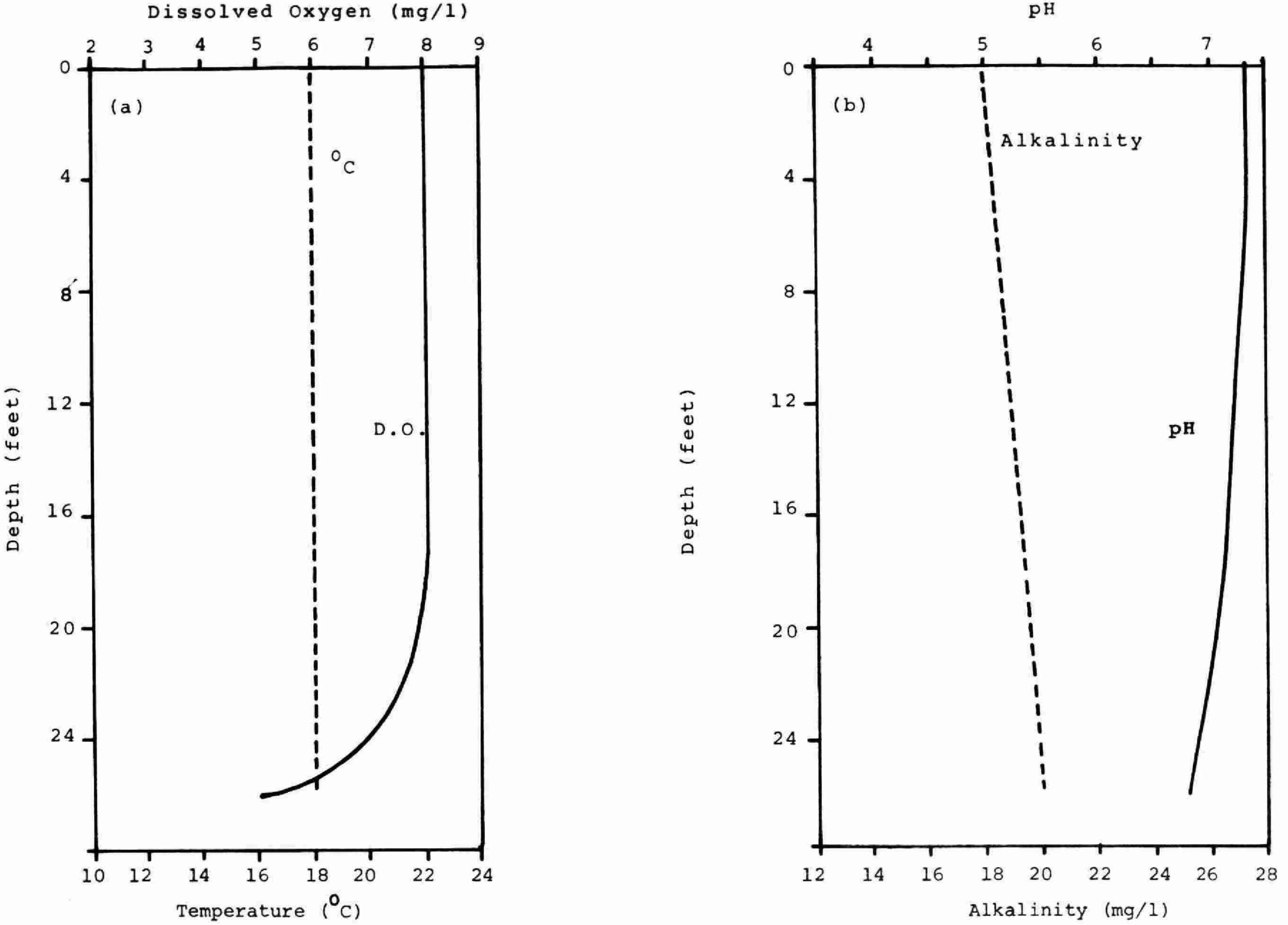

Figure 2: Profiles of (a) dissolved oxygen and temperature and (b) alkalinity and pH at a centrally located station in Lulu Lake on August 26, 1971.

Table 1: Secchi disc (feet) and chlorophyll a data (μgm/l) collected from Lulu Lake on eleven sampling dates during the summer of 1971.

Date		Secchi disc (feet)	Chlorophyll a (μgm/l)
July 11		8.0	5.3
July 18		10.0	2.9
July 25		6.0	3.1
August 1		5.5	4.1
August 8		8.0	0.4
August 22		6.5	8.2
August 29		6.5	10.0
September 5		6.0	6.0
September 19		4.5	2.0
September 26		4.0	7.9
October 3		5.5	5.7
	Mean	6.3	5.1

measurements between 9.8 and 16.4 feet would be mesotrophic; that is, they have a moderate supply of nutrients, plant growths and biological production. On the basis of these guidelines alone, Lulu Lake, having a mean Secchi disc reading of 6.3 feet, would be decidedly eutrophic.

Water chemistry

Alkalinity and pH

Moyle (1949) considered a total alkalinity of 40 mg/l to be a natural separation point between soft and hard waters. The soft-water nature of Lulu Lake was evinced by alkalinity recordings between 18 and 20 mg/l (Figure 2b). The pH was slightly higher in the surface waters (7.3) than in the deeper strata (6.4) suggesting that chemical reducing conditions prevailed at the sediment-water interface (Figure 2b).

Dissolved oxygen

Dissolved oxygen concentrations (Figure 2a) were generally uniform with depth. The temperature-oxygen regime of the lake indicates a suitable environment for most warm-water species of game and pan fish.

Nutrient considerations

Nutrient considerations in Lulu Lake are summarized in Table 2. In general, phosphorus, nitrogen and silica concentrations were uniform between surface and bottom indicating complete vertical mixing owing to wind and wave activities. Generally, troublesome levels of algae and vascular aquatics may appear when total phosphorus concentrations approximating 0.020 mg/l are attained. A total phosphorus concentration of 0.025 mg/l exceeded this limit indicating that sufficient phosphorus levels to promote excessive plant growths currently characterize the

Table 2: Nutrient conditions in the euphotic zone (taken as composite through 12 feet) and at 26 feet of depth in Lulu Lake, August 26, 1971

Sample	Total Phosphorus (mg/l P)	Nitrogen (mg/l N)				Silica (mg/l SiO_2)
		Total Kjeldahl	Free Ammonia	Nitrate	Nitrite	
Euphotic Zone	0.025	0.52	0.05	<.01	.003	0.15
26 feet	0.029	0.55	0.07	<.01	.002	0.47

waters of Lulu Lake. By the same token, surface water total Kjeldahl nitrogen concentrations were relatively high confirming the enriched nature of the lake.

Chlorophyll *a*

Chlorophyll *a* concentrations (micrograms per liter) for the eleven sampling days are indicated in Table I. Experience has indicated that concentrations between 0 and 3 ugm/l on a yearly average are low and indicate low to moderate algal densities. Concentrations between 3 and 6 ugm/l, although moderately high, may be considered acceptable for most water-oriented recreational pursuits. Levels exceeding 6 ugm/l indicate high algal densities. At these higher levels, deterioration of water quality for recreational activities such as swimming and water-skiing may be expected as well as a reduction in the lake's aesthetic quality. As indicated in Table I, a wide range in chlorophyll concentrations was reported from Lulu Lake; however, concern is expressed relative to the high "borderline values" recorded during the latter part of August.

Chlorophyll *a* - Secchi disc relationships

As indicated earlier, chlorophyll *a* measures the amount of photosynthetic green pigment in algae while water clarity, which is one of the most important parameters used in defining the trophic condition of a lake, is determined by means of a Secchi disc. Personnel of the Biology Section noted that a near-hyperbolic relationship exists between chlorophyll *a* concentrations and Secchi disc readings for lakes

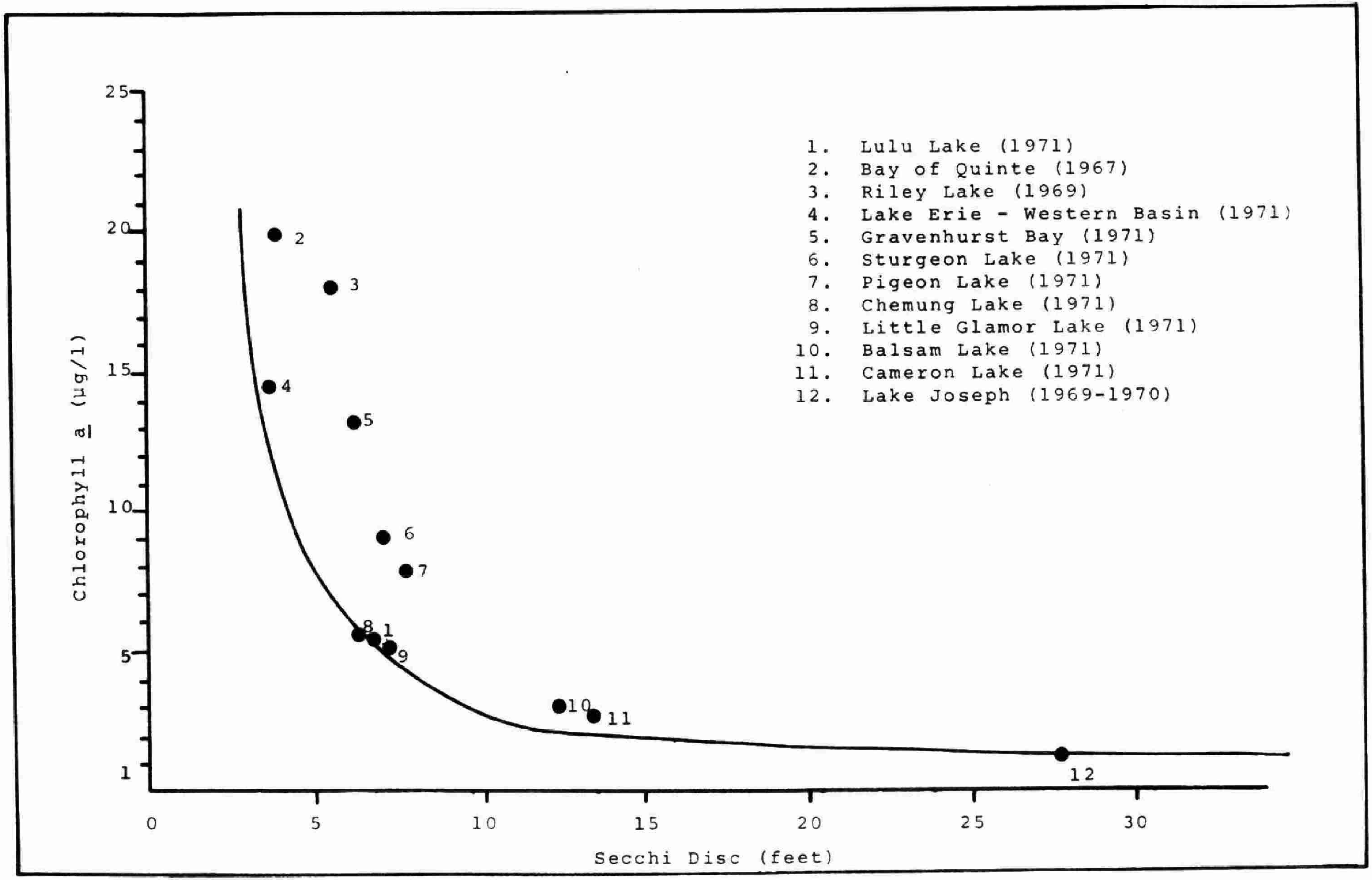

Figure 3: The relationship between chlorophyll a and Secchi disc for Lulu Lake and other well-known recreational lakes in Ontario. All data are yearly means.

of Precambrian origin. Figure 3 describes this relationship for 945 sets of data collected from approximately sixty lakes in the Province. Points for eutrophic or highly enriched lakes are characterized by high chlorophyll a concentrations and poor water clarity and are situated along the vertical axis of the hyperbola while oligotrophic waters which have low chlorophyll a levels and allow significant light penetration lie along the horizontal limb. Data for mesotrophic lakes would be dispersed about the middle section of the curve. Chlorophyll a and Secchi disc data for Lulu Lake are clearly positioned midway between the mesotrophic or moderately productive waters of Balsam and Cameron Lakes of the Kawartha Lakes - Trent River System, and the eutrophic or highly enriched Riley Lake, Gravenhurst Bay, Bay of Quinte and Western Basin of Lake Erie. On the basis of the information available, Lulu Lake is in the early stages of eutrophy.

Phytoplankton populations

Standing stocks of phytoplankton are presented in Table 3. Although a single sample is insufficient to interpret satisfactorily, the biological quality of the water, the relatively high total areal standard unit count (i.e. 3,867 a.s.u. per ml) clearly indicates an enriched habitat. As indicated, the blue-green algae Anabaena flos-aquae, Aphanothece, Lyngbya, Gomphosphaeria and Aphanizomenon flos-aquae dominated; phytoplankton communities dominated by such species - especially Anabaena flos-aquae ad Aphanazomenon flos-aquae, types which commonly form objectionable mid-summer and early fall "water blooms" - are

Table 3: Summary of phytoplankton data collected as a composite through the euphotic zone (12 feet) in Lulu Lake, August 26, 1971. All results are expressed as areal standard units per millilitre.

Algal Type		Areal Standard Units per millilitre
Blue-greens		
Anabaena		2,253
Aphanizomenon		98
Chroococcus		14
Gomphosphaenia		83
Lyngbya		213
Oscillatoria		213
Merismopedia		5
Aphanocapsa		38
Aphanothece		652
	Sub total	3,356
Flagellates		
Chlamydomonas		194
Cryptomonas		63
Dinobryon		5
Euglena		9
Rhodomonas		6
Phacus		57
Unknown chrysophyte		1
	Sub total	335
Greens		
Coelastrum		9
Oocystis		4
Scenedesmus		4
Sphaerocystis		31
Crucigenia		1
Quadrigula		14
	Sub total	63
Diatoms		
Asterionella		22
Fragilaria		59
Melosira		9
Rhizosolenia		21
Eunotia		2
	Sub total	113
	TOTAL	3,867

characteristic of artificially enriched waters.

Phosphorus, cottage development and artificial enrichment

Over the past few years investigations on a number of recreational lakes in Precambrian country have indicated that lakes are aging at accelerated rates. Cottagers have complained of reduced water clarity; growths of algae on rocks, docks, boats or boathouses; the development of extensive weed beds; and the disappearance of deep-water species of game fish. A questionnaire circulated to cottagers throughout Lakes Muskoka, Joseph and Rosseau revealed that some 70% of those who have frequented the area in excess of 15 years detect signs of deteriorating water quality (Michalski and Robinson 1971). Usually smaller lakes are first to develop symptoms of accelerating enrichment. However, for the first time on record, a short-lived blue-green algal bloom materialized in October of 1971 over the entire surface of Lake Muskoka - a relatively large lake (12,032 acres). These facts have provided strong circumstantial evidence that inputs associated with cottage wastes are responsible for increasing problems of eutrophication. No one really understands how effective presently accepted waste treatment practises are in preventing the translocation of nutrients to the water, particularly where coarse-textured, light soils overlay impervious bedrock. However, evidence is slowly appearing which reveals that conventional septic tank-tile field systems located on the shoreline of a lake do not adequately retain nutrients. For example, Hall (1970) determined that the phosphorus fixation capacity of three Maine soil types (Adams, Plaisted and Paxton) would be exceeded if these soils were utilized as tile beds. The author stressed

"....extreme care should be used on locating septic tank-drainfield waste water disposal systems adjacent to lakes or other surface waters that may be subjected to cultural eutrophication". Also, Hall (1970) confirmed that soils which allow for "....the rapid passage of water through them are not as effective in removing phosphorus as those which present more of an obstruction to the passage of water....the better the septic tank-drainfield system operates as a wastewater disposal system, the poorer it operates as a means of protecting lake or ground waters from polluting elements". Finally, Hall (1970) indicated that for the Adams soil, freezing and thawing (i.e. following the spring freshet) are instrumental in leaching phosphorus initially retained by the soil "....from the drainfield areas and its transport to other areas auch as the lake itself". Bennett (1970) states, "One of the drawbacks to locating housing developments around lakes is that such developments often are not connected with sewage-disposal systems; rather, each house is supplied with its own septic tank and tile field. If the house is close enough to the lake to benefit aesthetically from it, the field must, of necessity, be laid in land sloping toward the lake. Eventually, effluents from these tile fields enter the lake and, because they carry phosphates and nitrates, they act as fertilizers, which stimulate aquatic vegetation and create nuisance problems. Prospective home owners who contemplate the purchase of lots for permanent homes on small lakes should insist on a sewage system which will carry all effluents away from the lake". The Water Sub-Committee of the Natural Resources Committee of State Agencies for the State of Wisconsin in a report dated January 31, 1967 estimated that the phosphorus contribution reaching natural water courses from septic tank-tile field beds was 0.2 lbs/capita/year. Finally, Michalski et al. (1973) recently presented data which indicated that the sandy Precambrian soils may be of minimal value as tile bed soils because their capacity to retain phosphorus is limited and a considerable proportion may be held only temporarily, that is, until percolating rainwater washes phosphorus through to base flows.

The aforementioned facts pertaining to the current enriched status of Lulu Lake as well as recent information which demonstrates that soils indigenous to the study area may be of minimal value in retaining phosphorus, indicate that nutrients from artificial sources are largely responsible for creating problems of accelerated eutrophy in Lulu Lake. Further development of the lake should not be considered unless it can be conclusively demonstrated that the sewage facilities provided will not undermine future water quality. Facilities provided should prevent organic wastes, bacteria and/or nutrients from gaining access to the lake.

APPENDIX A

WATER QUALITY IN RECREATIONAL LAKES

Bacteriological Water Quality

For many years, cottagers have generally equated water quality with the presence or absence of coliform or fecal coliform bacteria in the water. Certainly, localized bacteriological problems in recreational lakes associated with inadequate or malfunctioning cottage waste treatment systems are still all too frequent.

In June, 1970, the Ontario Water Resources Commission (now within the Ministry of the Environment) implemented changes in the criteria for bacteriological quality of water. Under these criteria, water used for total body contact recreational activities is impaired when the coliform, fecal coliform and/or enterococcus geometric mean densities exceed 1,000, 100 and/or 20 per 100 ml, respectively, in a series of at least ten samples per month, including samples collected during weekend periods (OWRC 1970).

Separate criteria are in force for private water supplies for individual dwellings and cottages. The raw water must be of such quality that it can be used with a minimum of treatment, limited to disinfection, filtration and/or softening. Microbiological criteria for private water supplies is provided in Table I of the Appendix.

Although bacteriological contamination is undoubtedly of most direct significance to cottagers, this type of pollution can be readily identified and through the implementation of effective controls, a rapid return to satisfactory water quality can be achieved.

Eutrophication

It is only within recent years that the more lasting effects of a type of pollution best described as nutrient enrichment have become clearly recognized. This process, scientifically known as EUTROPHICATION, is associated with sedimentation and increases in the dissolved mineral content of a lake - specifically, substances such as phosphates, nitrates, carbonates and numerous trace elements - increases which occur as a result of rainfall, land runoff and percolation of soil-water to the lake. Higher concentrations of these dissolved materials cause the water to become progressively more fertile and productive, stimulating the development of free-floating microscopic plants called phytoplankton - generally referred to as algae.

Algae are normal inhabitants of virtually all surface waters and fulfill an essential role in maintaining a balanced condition in the aquatic environment. They not only provide the entire nutritional base for a complex aquatic food web which includes the production of game and commercial fish species, but produce and release oxygen to the water which is vital to the metabolism of fish and all other forms of aquatic life.

The natural development of algae is regulated not only by nutritional factors, as previously mentioned, but by environmental factors such as temperature, the intensity and duration of illumination (sunlight) and by physical factors such as size, depth and shape of the lake bottom. Thus, the corresponding rates of eutrophication in different lakes are determined by varying combinations of extrinsic and intrinsic features.

All lakes, even the largest and deepest, are transitory bodies of water and are continually undergoing a gradual process of change from youth to maturity to old age, or in limnological terms, from oligotrophy to mesotrophy to eutrophy. Progressing even further, death of a lake can be equated to the onset of a "swamp" or "marsh" condition. In small, shallow lakes, this entire process may have occurred in some cases within a single century following the glacial retreat; in other instances, the process is well advanced, and still going on, and in many larger, deeper lakes remote from human influences, significant changes can only be measured on a geologic time scale (i.e. thousands of millions of years).

Major differences in Ontario Lakes

Lakes surrounded by granitic bedrock and the sparse infertile soils of the Precambrian Shield which covers Muskoka, Haliburton and areas further north are characterized by low rates of algal production and consequently age less than lakes surrounded by the deeper, richer soils of Southern Ontario. Correspondingly, "nutrient-poor" lakes on the "Shield" having moderate to extreme depth, generally support a relatively low production of cold-water species such as lake trout, whitefish and herring. Such lakes are characteristically clear and well-suited to swimming and other water-oriented recreational pursuits. Also, the deeper waters are well-supplied with oxygen throughout the year. This latter condition relates to the low algal production and concomitant lack of any significant oxygen depletion associated with the decomposition of algae at the lake bottom.

Alternatively, fertile lakes, such as the Kawarthas, are more turbid owing to the increased phytoplankton production and presence of suspended particulate matter. They contain substantial growth beds of submergent leafy vegetation such as water milfoil, elodea, coontail and pondweeds and produce higher yields of warm-water species such as walleye and bass.

Adequate levels of dissolved oxygen are generally present from surface to bottom since these lakes are shallow and benefit from the high level of photosynthetic activity, as well as surface aeration and complete vertical mixing during periods of windy weather. The Kawartha Lakes have been extremely productive for many years and can be considered as naturally eutrophic waters.

Artificial fertilization has been the overriding factor which has created different types of problems in these two major types of lakes. Enrichment studies have been carried out by personnel of the Ministry of the Environment at the request of concerned cottagers on lakes in northern and central Ontario such as Little Panache (near Sudbury), Riley Lakes (near Gravenhurst), Silver Lake (near Port Carling), Big Straggle Lake (near Bancroft) and several others which can be considered representative of most lakes on the Shield. To varying degrees, these investigations revealed the classical evidence and undesirable features of induced fertilization in these thermally stratified lakes. Affected lakes are characterized by increased phytoplankton levels, the development of high numbers of blue-green algae in late summer and reduced pH and dissolved oxygen concentrations in the deeper waters associated with the decomposition of settled algae and higher carbon dioxide, nutrient and iron levels, again particularly evident in the deeper water where reducing conditions prevail.

Associated undesirable effects of induced eutrophication in one or more of these situations were a reduction in water clarity and related impairment of the recreational and aesthetic qualities of the water, objectionable accumulations of blue-green algae along shorelines and associated malodorous conditions on decomposition, a decrease in the quality of the water for drinking and domestic purposes including clogging of water intake filters, a reduction of the area suitable for game fish owing to oxygen reduction in the deeper waters and a further reduction in fish production through elimination of desirable fish-food organisms.

In lakes like the Kawarthas, on the other hand, increased enrichment resulting from agricultural runoff, urbanization along the system and inadequate containment of cottage wastes has placed increasing stress on an already productive aquatic environment. Here, artificial nutrient inputs have intensified the production and frequency of blooms of blue-green algae and have enhanced the production of aquatic plants to the point where many activities such as swimming, water-skiing and unimpeded boating are practically impossible. Prolonged periods of hot, calm weather have periodically caused decomposition of algae and aquatic plants in isolated bays where limited water exchange has resulted in dissolved oxygen depletion and accompanying fish mortalities. Also, periodic winter kills of fish resulting from organic decomposition have been a recurring problem. It is certain that heavy densities of weeds in many areas interfere with the harvest of

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